LONG-TERM OUTCOMES AFTER ULNAR COLLATERAL LIGAMENT RECONSTRUCTION IN COMPETITIVE BASEBALL PLAYERS: A MINIMUM OF 10 YEARS FOLLOW-UP

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ABSTRACT

Background: Ulnar collateral ligament (UCL) insufficiency was previously considered a career-ending injury in baseball players as these throwing athletes were unable to reach or maintain peak performance because no reproducible surgical technique was available for repair or reconstruction. However, the introduction of a reliable modern-day technique for UCL reconstruction has afforded baseball players with excellent results, with return to the same or higher level play from 80% to 90% of the time. Despite these successful results, all previous studies have described only short-term reconstruction outcomes, with less than 3.5 years of average follow-up.

Purpose: The purpose of this investigation is to evaluate long-term outcomes (minimum 10-year follow-up) after UCL reconstruction in baseball players to elucidate critical information pertaining to the ultimate level and longevity of return to competitive play as well as the long-term disability, satisfaction, and subjective findings.

Study Design: Case Series

Methods: We identified all UCL reconstructions performed on competitive baseball players by the senior author with a minimum 10-year follow-up. Surgical data were collected prospectively and patients were surveyed retrospectively by telephone using a questionnaire, Conway scale, and Disabilities of the Arm, Shoulder and Hand (DASH) scoring system, including work and
sports modules, to determine baseball and post-baseball career outcomes at a minimum of 10 years after surgery.

**Results:** Two hundred fifty-six of 313 patients (82%) were contacted at an average of 12.6 years (range, 10.1 to 17.1 years). The average age at the time of surgery was 22.1 years (range, 15.9 to 41.7 years), and the average age at follow-up was 34.7 years (range, 26.4 to 54.5 years). In terms of baseball career outcomes, 83% of these baseball players (89% pitchers) were able to return to the same or higher level of competition in less than one year, but return to same or higher level of play results did vary according to pre-operative level of play (major league: 79%; minor league: 76%; college: 92%; high school: 79%). (p = 0.049) Baseball career longevity after UCL reconstruction was 3.6 years in general and 2.9 years at the same or higher level of play, but major league and minor league baseball players returned for a longer period of time after surgery (p< 0.001). Concomitant procedures at the time of UCL reconstruction (p = 0.007) and post-operative elbow surgery (p= 0.015) resulted in a longer career after primary UCL reconstruction. Baseball retirement typically occurred for reasons other than the elbow (86%), except in cases of a post-operative elbow surgery (p < 0.001) or ulnar neuropathy (p = 0.018). Many baseball players also had shoulder problems (34%) or surgery (25%) during the course of their baseball career, and these occurrences most often resulted in retirement due to the shoulder. (p < 0.001) At long-term follow-up, 93% of patients were satisfied, with few reports of persistent elbow pain (3%) and limitation of elbow function (5%) during activities of daily living. In addition, 92% of the baseball players were able to throw currently without elbow pain, and 98% were still able to participate in throwing activities at least on a recreational level. According to the overall DASH, DASH work module, and DASH sports module scoring systems, 10 year minimum follow-up
scores were 0.80, 1.10, and 2.88, respectively. In addition, many patients were participating in activity/manual labor related jobs (58%) and baseball related activities (61%), including coaching and/or instruction.

**Conclusion:** Long-term follow-up of UCL reconstruction in baseball players indicates that most patients are satisfied, with few reports of persistent elbow pain and limitation of elbow function during activities of daily living. During their baseball career, most of these athletes are able to return to the same or higher level of competition in less than one year, with acceptable career longevity and retirement typically for reasons other than the elbow. Regardless of the elbow history, a concomitant history of shoulder problems and/or surgery will most often result in retirement secondary to the shoulder. According to our standardized disability and outcome scale, patients also have excellent results in comparison to the general population after UCL reconstruction during daily, work, and sporting activities. In fact, many patients are able to participate in activity/manual labor related jobs and baseball related activities, including coaching and/or instruction. Overall, baseball players who undergo UCL reconstruction for UCL insufficiency during their baseball career can expect excellent long-term follow-up outcomes in relation to their baseball and post-baseball career, with overall patient satisfaction in the setting of few cases of persistent elbow disability.

**Key Words:** Elbow, Ulnar Collateral Ligament Insufficiency, Ulnar Collateral Ligament Reconstruction; Tommy John Surgery; Baseball
Elbow problems in throwing athletes were first documented in professional baseball players in 1941 by Bennett. During the late cocking and acceleration phases of the throwing motion, the elbow is subjected to excessive valgus stresses which generate tremendous forces to the medial structures of the elbow, and most valgus moments are resisted primarily by the anterior bundle of the ulnar collateral ligament (UCL). Repetitive overloading associated with the throwing motion causes microscopic tears in the UCL with subsequent ligament attenuation and failure with the onset of degenerative changes, inability to throw, and chronic, disabling elbow pain. Jobe and colleagues were the first to perform a standard operative technique utilizing a figure-of-eight ligament configuration. Tunnels were utilized for repair or reconstruction of the anterior band of the UCL along with submuscular ulnar nerve transposition. Our preferred operative procedure has employed a modification of the original Jobe technique by elevating the flexor carpi ulnaris (FCU) anteriorly and performing a subcutaneous ulnar nerve transposition. We recently published our short-term outcomes for UCL reconstruction in 1281 throwing athletes, including 743 with a minimum of 2-year follow-up. In this report, our UCL reconstruction technique resulted in successful return to the same or higher level of play for most athletes (83%) in less than 1 year. Our reported results are consistent with other studies detailing that UCL reconstruction may reliably return 80% to 90% of overhead athletes, including baseball players, to their previous or...
Despite these successful results, all previous studies have described only short-term reconstruction outcomes, with less than 3.5 years of average follow-up. Conway and colleagues, in the only known study with a follow-up period of greater than 3.5 years, evaluated Jobe’s original surgical approach (including common flexor-pronator takedown and submuscular ulnar nerve transposition) at an average follow-up of 6.3 years. Therefore, the purpose of our investigation is to evaluate long-term outcomes after UCL reconstruction in baseball players, including a minimum 10-year follow-up. As no known studies exist which analyze long-term outcomes after UCL reconstruction in baseball players, this study will provide critical information pertaining to the ultimate level and longevity of return to competitive play as well as the long-term disability, satisfaction, and subjective outcomes. We hypothesize that UCL reconstruction will allow most baseball players to return to the same or higher level of competitive play, result in a high level of overall satisfaction, and provide high long-term subjective ratings with little long-term disability.

**MATERIALS AND METHODS**

We identified all UCL reconstructions performed on competitive baseball players by the senior author with a minimum 10-year follow-up. As previously described, UCL reconstruction was performed through a flexor-pronator muscle elevation approach using a figure-of-8 configuration with an autograft tendon in conjunction with a subcutaneous ulnar nerve transposition. (Figure
1) After surgery, a standardized post-operative 4-phase rehabilitation program for UCL reconstruction was implemented as previously described by Wilk and colleagues.²¹

Pre-operative data were obtained prospectively from all patients, including age, position, pre-operative level of play, and history of previous shoulder and/or elbow injury. Surgical data were then obtained prospectively for all subjects, including surgery date, graft choice, additional concomitant procedures, and intra-operative complications. All patients were then contacted retrospectively by telephone after a minimum 10-year follow-up period to ascertain information relating to their competitive baseball and post-baseball careers, if applicable.

Baseball Career Data

In terms of their baseball career, each subject’s pre-operative career was evaluated in terms of longevity and levels of competition. Pre-operative competition was counted as the number of active seasons played since the beginning of high school. All pre-operative and post-operative years during which patients were inactive or retired (e.g. disabled list, rehabilitation period, etc.) were not considered active years of play. Furthermore, recreational baseball, including youth, intramural, and adult recreational leagues were not considered active years of competitive play.

Post-operative outcomes for each subject were classified using a modified version of the Conway Scale.⁵ This modified Conway Scale ranks outcomes numerically based on the highest post-operative level of competition achieved by the subject, as compared to his level of competition at the time of surgery. Outcome scores range from 1 to 4, including 1 as “excellent”, 2 as “good”, 3 as “fair”, and 4 as “poor” outcomes. For the current study, the subjects identified as a “Conway
“1” were further divided into 1a and 1b. Conway 1a represented an individual who returned to a higher level of competition for at least one season, and 1b characterized a return to the same pre-operative level of competition for at least one season.

Each patient’s time to return to throwing and return to competition were confirmed. Return to throwing was defined as the length of time from the date of surgery to beginning the interval throwing program. Return to competition was defined as the length of time from the date of surgery until returning to game competition, if applicable. Additional information was obtained, including post-operative playing status, position, level of play, limitations, and reason for retirement, when applicable. Finally, pre-operative and post-operative elbow and shoulder problems and surgeries were noted.

Post-Baseball Career Data

The remainder of the interview focused on the player’s current health and welfare. These data were collected to evaluate the overall elbow functionality, limitations, and symptoms experienced by each subject in a day to day setting of daily, work, and recreational activities. Variables assessed included overall satisfaction of the UCL reconstruction procedure, day-to-day elbow pain, limitations in elbow function, and elbow pain with recreational throwing. Based on each subject’s current level of competitive throwing, a current Conway score was also assigned, and the current competition status was recorded (active, inactive, or retired). Finally, the Disabilities of the Arm, Shoulder and Hand (DASH) scoring system and its optional work and sports modules were utilized to further evaluate the current symptoms and functionality of the patient’s elbow.
The distribution of post-operative and current Conway scores were identified, as were the number of each graft type (ipsilateral palmaris longus, contralateral palmaris longus, contralateral gracilis, and plantaris), reason for retirement (elbow, shoulder, other injury, or non-injury), and the frequency of concomitant injuries/surgeries at the time of UCL reconstruction. All of these data was evaluated as based upon the overall group of subjects as well as individual levels of play, including major league, minor league, college, and high school. Furthermore, the percent of individuals with additional elbow surgeries, additional pre-operative elbow surgeries, additional post-operative elbow surgeries, shoulder problems, shoulder surgeries, and post-operative neurological problems were also calculated. The percent of subjects involved in post-baseball career baseball-related activities and manual labor/activity related jobs were also calculated. In addition, the percent of those individuals involved in throwing sports, non-throwing sports, and actively competing in baseball at a competitive level were assessed. The percent of subjects responding “yes” and “no” to elbow pain, limitations with elbow function, and elbow pain when throwing were also calculated. A mean and standard deviation was calculated for the time for return to throwing, time for return to game competition, length of post-operative career, DASH scores, work module DASH scores, and sports module DASH scores.

Further statistical analyses were performed for eight independent variables, including graft type, concomitant elbow procedures, shoulder problems, shoulder surgeries, additional elbow surgeries, additional prior elbow surgeries, additional post-operative elbow surgeries, and post-operative neurological problems. For each of these independent variables, six dependent
variables were evaluated, including post-operative Conway score, post-operative career
longevity, retirement etiology, DASH score, work DASH module, and sports DASH module.
Independent t-tests were used to compare the number of years of post-operative competition,
DASH score, work DASH module, and sports DASH module, except for analyses of these
variables against graft types, which required a one-way ANOVA. For comparison of post-
operative Conway scores, Mann-Whitney U tests were utilized, except for graft types, for which
a Kruskal-Wallis test was performed. Finally, a chi-squared test was utilized for analyzing
reasons for retirement. For all tests, the alpha level was set at 0.05.

RESULTS

Three hundred thirteen baseball players with prospectively collected surgical data were eligible
for 10-year minimum follow-up. Two hundred fifty-six athletes (82%) were contacted for
follow-up at an average of 12.6 years (range, 10.1 to 17.1 years). The remaining 57 patients
could not be reached despite multiple attempts. Of the 256 contacted baseball players, 228 (89%)
were pitchers and 28 (11%) were position players, including 10 catchers, 8 outfielders, 6 multi-
position players, and 4 infielders. In terms of level of play, 24 baseball players were major
league, 88 were minor league, 104 were collegiate, and 40 were high school athletes.

The average age at the time of surgery was 22.1 years (range, 15.9 to 41.7 years), and the
average age at follow-up was 34.7 years (range, 26.4 to 54.5 years). Sources of graft tissue
included ipsilateral palmaris (71%), contralateral gracilis (14%), contralateral palmaris (9%), and
plantaris (6%). Thirteen percent (33 players) of the baseball players had at least one pre-operative elbow surgery and thirty-four percent (87 players) had a concomitant injury addressed at the time of surgery with both occurrences varying depending upon the pre-operative level of play. (Table 1) Baseball players returned to throwing at an average of 4.2 months ± 0.9 (range, 2 to 8 months) and game competition at an average of 11.6 months ± 3.5 (range, 5 to 24 months).

**Baseball Career Data**

At a minimum of 10-year follow-up, 243 (95%) of the baseball players were retired, while only 13 (5%) were still active in competitive baseball. Some baseball players did require post-operative elbow surgery or experienced post-operative complications after their primary UCL reconstruction. Nineteen percent (49 players) had at least one post-operative elbow surgery. In fact, 49 players required a total of 59 post-operative surgeries after the primary UCL reconstruction. Of these 59 post-operative surgeries, 30 (51%) were performed for posteromedial impingement which included osteophyte excision. Of the remaining 29 post-operative surgeries, there were eight arthroscopic or open elbow debridements for arthrofibrosis, six revision UCL reconstructions for UCL graft tears, four of six players with medial epicondyle avulsion fractures underwent open reduction internal fixation (two required only immobilization), four ulnar nerve decompressions in three players for persistent ulnar nerve symptoms after ulnar nerve transposition, two lateral elbow debridements for radiocapitellar disease, two general elbow debridements, one of three players with flexor-pronator tears required flexor-pronator repair (two required only non-operative treatment), one hardware removal after open reduction internal fixation of a medial epicondyle avulsion fracture, and one irrigation and debridement for a post-operative infection. There was a statistically significant difference between the occurrence of
post-operative elbow surgery in the major and minor league players compared to the college and high school players. (Table 2) In terms of post-operative ulnar nerve symptoms, 24% of the baseball players had transient ulnar neuropraxia after their UCL reconstruction, but this finding did not vary depending upon pre-operative level of play, including 17% major league, 23% minor league, 30% college, and 18% high school athletes.

Many of the baseball players had shoulder problems or surgery during the course of their baseball career, as 87 players (36%) had shoulder problems and 65 players (25%) had shoulder surgery. The occurrence of shoulder problems and/or surgery varied as based upon their pre-operative level of play, including 46% and 42% for major league, 38% and 30% for minor league, 32% and 23% for college, and 25% and 13% for high school athletes, respectively. Although there was no statistically significant difference in likelihood of a shoulder problem as based upon level of play, there was a statistically significant difference between the occurrence of shoulder surgery in the major and minor league players compared to the college and high school players. (Table 2)

Return to Play Data

According to the Conway scale, 83% of the baseball players returned to the same or higher level of play and varied by pre-operative level of play, which can be visualized in Table 3. In fact, college players (92%) more often returned to the same or higher level of play than major league (79%), minor league (76%), and high school (79%) baseball players. (p = 0.049) Return to play data was also evaluated to determine statistical significance as based upon several independent variables. (Table 4) There was no statistically significant difference between return to play as
based upon graft choice (p=0.222) and concomitant injury treatment (p=0.522) at the time of UCL reconstruction. For those patients with post-operative transient ulnar neuropraxia, there was also no statistically significant difference in return to play. (p = 0.642) Return to play according to the Conway scale was not statistically different for those players with a history of an additional elbow surgery. (p = 0.286) This occurrence included whether the additional surgery occurred in the pre-operative (p = 0.590) or post-operative (p = 0.182) setting as referenced to the primary UCL reconstruction. In addition, there was no statistically significant difference in return to play for those players having a history of shoulder problems (p = 0.182) or surgery (p = 0.698).

**Longevity Data**

The overall length of a baseball career after UCL reconstruction was 3.6 years and varied when based upon pre-operative level of play. (Table 5) When assessing career longevity only related to return to the same or higher level of play, the overall baseball career length was 2.9 years and also varied when based upon pre-operative level of play. (Table 5) Longevity data was also evaluated to determine statistical significance as based upon several independent variables. (Table 6) When evaluating graft choice and transient ulnar neuropraxia, there was no statistically significant difference in length of post-operative career at the same or higher level of play. For patients that had a concomitant injury treatment at the time of primary UCL reconstruction, the post-operative career was statistically longer. The post-operative career was not statistically longer for those players having a history of an additional elbow surgery (p = 0.072) or pre-operative elbow surgery when compared to the primary UCL reconstruction (p = 0.847). However, this occurrence was statistically significant for those players having post-operative
elbow surgery when compared to the primary UCL reconstruction. For shoulder pathology, there was no statistically significant difference in length of post-operative career for those players having a history of shoulder problems; however, players who underwent shoulder surgery at some point were more likely to have a longer post-operative career after primary UCL reconstruction.

Retirement Etiology Data

Upon retirement from competitive baseball, most athletes indicated the reason for retirement was based upon a non-injury related etiology followed by shoulder problems, elbow problems, and other injuries. (Table 5) Retirement etiology data was also evaluated to determine statistical significance as based upon several independent variables. (Table 7) There was no statistically significant difference for retirement etiology as based upon graft choice \(p = 0.186\) or concomitant injury treatment \(p = 0.283\) at the time of UCL reconstruction. However, patients with post-operative transient ulnar neuopraxia were more likely to retire due to the elbow \(p = 0.018\). When baseball players had an additional elbow surgery \(p < 0.001\), they were more likely to retire due to the elbow than from another etiology. This included whether the additional elbow surgery was in the pre-operative setting \(p = 0.027\) or the post-operative setting in relation to the primary UCL reconstruction \(p < 0.001\). However, those players who had a history of shoulder problems \(p < 0.001\) or surgery \(p < 0.001\) were more likely to retire due to the shoulder than from another etiology.
**Post-Baseball Career Data**

At 10-year minimum follow-up, 93% of the baseball players were satisfied with the results of their UCL reconstruction. Only 3% of the baseball players had elbow pain, while only 5% had a perceived limitation in elbow function. In addition, 92% of the baseball players were able to throw currently without elbow pain, and 98% were still able to participate in throwing activities at least on a recreational level.

The assessment of DASH scoring showed overall good scores as the overall DASH, DASH work module, and DASH sports module scores were 0.80 ± 4.43, 1.10 ± 6.90, and 2.88 ± 11.91, respectively. There was no statistical difference between pre-operative level of play and the overall DASH (p = 0.334), DASH work module (p = 0.331), and DASH sports module (p = 0.205). Post-Baseball Career DASH data was also evaluated to determine statistical significance as based upon several independent variables. (Table 8)

Based upon graft choice, concomitant injury treatment at the time of UCL reconstruction, shoulder problems, and shoulder surgery, there was no statistically significant difference between DASH, work module, and sports module scores related to elbow disability. For those patients with post-operative transient ulnar neuropraxia, there was a statistically significant difference in lower DASH and DASH sports module scores in relation to elbow disability; however, there was no difference in DASH work module scores. When assessing whether these baseball players had a pre-operative elbow surgery, there was no statistically significant difference in all DASH scores; however, post-operative elbow surgery resulted in a statistically significant lower overall DASH and DASH sports module scores but not DASH work module
scores. After their competitive baseball careers, many of these baseball athletes were involved in activity/manual labor related jobs and recreational endeavors, and participation occasionally varied as based upon pre-operative level of play. (Table 9)

DISCUSSION

UCL insufficiency was previously considered a career-ending injury in baseball players as these throwing athletes were unable to reach or maintain peak performance because no reproducible surgical technique was available for repair or reconstruction. With the introduction of a new technique by Dr. Frank Jobe, UCL reconstruction became a reliable procedure to enable throwing athletes to successfully return to play. With modern-day advances in surgical technique, more recent studies show that UCL reconstruction may reliably return athletes to their same or higher level of play from 80% to 90% of the time.\(^5, 8, 12, 17, 19\)

Despite these successful results, several questions still exist when considering long-term UCL outcomes. In fact, all current studies evaluating modern-day UCL reconstruction techniques assess only short-term outcomes concerning return to play with an average follow-up of no more than 3.5 years.\(^1, 3, 4, 6, 8, 9, 12, 15, 17, 18\) The lack of information relating to long-term outcomes, including baseball and post-baseball career data, provided the basis of our investigation.

Our results illustrated a successful return to same or higher level of play in 83% of our baseball players, with return to throwing in 4.2 months and return to game competition by 11.6 months.
In reference to our previous research by Cain and colleagues, the overall return to play results were similar at a longer follow-up interval. In fact, the previous 2-year follow-up case series showed 83% return to the same or higher level of play, with return to throwing in 4.4 months and return to game competition by 11.6 months. Our series also identified that 40% of players were actually able to return to a higher level of play after UCL reconstruction, and only 10% were unable to return to competitive baseball (9% recreational level and 1% unable).

When evaluating return to play after UCL reconstruction, our results are consistent with the previous studies, which report return to same or higher level of play in 80% to 90% of throwing athletes. An interesting finding was that successful return to the same or higher level of play varied upon the pre-operative level of play, with college players (92%) more often returning to the same or higher level of play than major league (79%), minor league (76%), and high school (79%) baseball players. These findings corresponded to our 2-year follow-up study by Cain and colleagues which showed better return to the same or higher level of play in college players (88%) than major league (76%), minor league (73%), or high school (83%) players.

Many clinicians have debated improved surgical outcomes with different surgical reconstruction techniques, including the figure-of-eight versus docking UCL reconstruction. When evaluating the literature, there are significant variations in the number of patients at each pre-operative level of play within all studies. In fact, the only docking reconstruction technique study with more than 35 patients by Dodson and colleagues reported 90% return to the same or higher level of play in a series that included mostly college baseball players (65.6%) as compared to professional (17.7%) and high school (16.7%) athletes. The only other series with more than 35
baseball players by Thompson and colleagues utilizing a figure-of-eight reconstruction reported
82% return to the same or higher level of play in a group of baseball players mostly comprised of
professional (65%) baseball players as compared to college (21.7%) or high school/recreational
(13.3%) athletes. Unfortunately, these two previous studies by Dodson and Thompson do not
delineate results as based upon pre-operative level of play. For all other studies involving
outcomes after UCL reconstruction, the small number of patients makes it difficult to evaluate
outcomes according to pre-operative level of play, as there are not enough patients to make
reasonable conclusions. Based upon our statistically significant findings of more successful
return to play in college players, we should be critical in evaluating the breakdown in pre-
operative level of play within each study, as results could vary depending upon the percent of
baseball players at each level of play. Although UCL reconstruction technique may still be an
important component for successful return to play, our results instead indicate that pre-operative
level of play is a critical consideration in assessing prognosis for return to the same or higher
level of play after UCL reconstruction.

In conjunction with previous studies evaluating UCL reconstruction outcomes, return to play did
not appear to be affected by graft choice. In addition, successful return to play as measured by
the Conway scale was not affected by other independent variables, including transient ulnar
neuropathy, additional elbow surgeries, shoulder problems, or shoulder surgery. Although no
other known studies have evaluated these variables in relation to UCL reconstruction, these
findings are not surprising considering the Conway scale is based upon short-term return to play
with excellent outcomes achieved with return to play for greater than only 12 months.
When assessing the inclusion of concomitant elbow procedures at the time of UCL reconstruction, return to play also appeared to not be affected. This finding should be taken in proper context as not all concomitant injuries confer the same prognosis. In fact, most previously reported concomitant procedures at the time of UCL reconstruction are related to the excision of a posteromedial olecranon osteophyte; however, other more serious injuries may be possible which require additional treatment. In a previously reported subpopulation of baseball players with concomitant flexor-pronator injuries, in fact, return to play was much lower with only 12.5% return to the same or higher level of play in 8 athletes. Therefore, surgeons should fully consider the type of concomitant procedure when discussing surgical prognosis with baseball players undergoing UCL reconstruction.

In terms of assessing post-operative baseball career longevity, our minimum of 10-year follow-up (average follow-up, 12.3 years) study appeared to be successful in encompassing our subjects’ complete baseball career as 95% were retired with only 5% still active in competitive baseball. Our study is the first known study evaluating longevity of a competitive baseball career after UCL reconstruction. All other modern-day UCL reconstruction outcome studies evaluate only short-term outcomes with no more than 3.5 years follow-up and/or utilize a short-term scoring scale (Conway scale – return to play based upon only 12 months or 1 season). The overall length of a baseball career after UCL reconstruction in our study was 3.6 years but varied when based upon pre-operative level of play. When accounting for only return to same or higher level of play (Conway 1), professional baseball players (major and minor league) interestingly had a shorter length to their post-operative professional baseball career, as they spent a portion of their time at a lower level of play. As baseball career longevity at the
same or higher level of play is multifactorial, this finding must be taken into proper context.

Although this finding could indicate that there is performance attrition after UCL reconstruction, this is not supported with the presented data, as there are not normative values to a baseball career, including in healthy and injured players. Nonetheless, it is critical to understand that successful return to play and continued play at the same level may require frequent evaluation and optimization of throwing mechanics, a well orchestrated throwing program for in-season and off-season athletes, continued monitoring of symptoms or fatigue, and close attention to pitch counts and/or innings limits. These are important factors that must be considered in all throwers to improve, maintain, or obtain health in these high functioning athletes.

In addition, professional baseball players also appeared to have a longer career after UCL reconstruction than amateur baseball players (college and high school). These occurrences are likely due to the fact that professional baseball players and teams have more expense and time invested into a successful return to play. However, these factors are highly dependent upon many player- and team-specific variables which we are not able to fully evaluate with our present study.

Baseball career longevity appeared to not be affected by graft choice or transient ulnar neuropathy. However, our results did show that career longevity was increased when a concomitant procedure at the time of primary UCL reconstruction or post-operative elbow surgery was performed. This is counterintuitive to what might be expected but can be possibly explained by several factors. The need for a concomitant elbow procedure or post-operative elbow surgery appeared greatly affected by pre-operative level of play, with professional
baseball players (major and minor league) more often requiring additional procedures when
compared to amateur baseball players (college and high school). As previously stated for our
return to play data, this may be related to several circumstances inherent to level of play and
invested time in competitive baseball that are not specifically dependent upon the additional
elvob procedure alone. Nonetheless, a higher level of pre-operative play, especially with
professional baseball players, will likely confer a risk of needing additional elbow surgery;
however, the ability to return to play for a significant number of years may not be adversely
affected.

When assessing baseball career longevity, the cause for retirement is extremely important and
typically related to injury and non-injury related etiologies. Within our study, we found that over
half (57%) of the reasons for retirement were related to non-injury causes; however, shoulder
and elbow problems, accounted for 36% of the retirement cases. Despite the reason for
retirement, graft choice and concomitant injury treatment did not affect the etiology. As might be
expected, however, baseball players with a post-operative elbow surgery or transient ulnar
neuropraxia were more likely to retire secondary to elbow problems.

Based upon previous research, shoulder and elbow injuries in baseball players may often occur
concurrently or in succession. Some authors have suggested that these upper extremity injuries
may be related in terms of cause and effect; however, little to no research has verified this
premise. A recent study by Dines and colleagues provided a possible association with
glenohumeral internal rotation deficit in the shoulder and UCL insufficiency in baseball players.7
These findings corroborated previous research by Putnam and colleagues which demonstrated
that shoulder internal rotation moments during throwing may provide the primary protection against valgus loads at the elbow.\textsuperscript{16} Although we did not find an association between retirement cause when compared to level of return to play, our findings illustrate that shoulder problems and/or surgery may be directly related to the cause of retirement. In addition, a shoulder surgery may impart increased career longevity; however, this finding again is likely multifactorial and related to many player- and team-specific variables which we are not able to fully evaluate with our present study. As shoulder problems (34\%) and shoulder surgery (25\%) were relatively common occurrences in our group of baseball players, these findings provide important prognostic information and accentuate the need for preventing and properly treating shoulder problems in these overhead athletes.

Although length and level of return to play as well as the cause of retirement are extremely important factors in assessing success after UCL reconstruction in baseball players, there are no known studies evaluating overall long-term disability and quality of life, especially when considering the post-baseball career. In addition to our success with returning baseball players to play, our results illustrate that UCL reconstruction may afford these athletes with excellent long-term outcomes for everyday life, including work and sporting activities. In fact, UCL reconstruction led to high satisfaction (93\%) with few cases of persistent elbow pain (3\%) and limitation in function (5\%).

DASH scores, including work and sports modules, also appear to indicate excellent results after long-term follow-up for UCL reconstruction. When comparing the DASH scores to normative data from the general population (10.10 ± 14.68), in fact, our group of baseball players had much
lower scores (0.80 ± 4.31). Upon factoring in work and sports related variables, our baseball players also had much lower work module (1.10 ± 6.90 versus 8.81 ± 18.37) and sports module (2.88 ± 11.91 versus 9.75 ± 22.72) scores when compared to those reported for the general population. Our lower overall scores when compared to the general population are likely related to the fact that our cohort of baseball players is an active group of young and healthy patients (average age at follow-up is 34.7 years); however, these excellent scores still indicate overall upper extremity health, including during work and sporting activities, in our post-operative cohort of patients with minimum 10-year follow-up after surgery. Although patients with post-operative elbow surgery or transient ulnar neuropraxia tended to have higher overall and sports module DASH scores, they were able to function at a high level during work related activities as their work module DASH scores remained low.

When assessing activity and manual labor activities, 98% of our baseball players are still able to participate in throwing activities at a recreational level, with 92% able to throw without elbow pain. Although a baseball career may be relatively short, most of our baseball players continued their involvement with baseball after their competitive career by participating in baseball-related activities, including coaching and/or instruction. As one might expect, professional baseball players are more likely to participate in baseball activities within their post-baseball career than amateur athletes. As surgeons most often equate UCL reconstruction success in relation to return to competitive play, these findings indicate that there may be long-term advantages to UCL reconstruction within the post-baseball career as many athletes continue to throw and even participate in organized baseball activities. However, one must take caution in interpreting these
findings, as there are no long-term studies evaluating quality of life and activities after non-operative treatment of UCL insufficiency in baseball players.

Despite our excellent results for baseball career and post-baseball career related variables, several limitations exist when evaluating the findings of this study. First, our rate of follow-up was 82%, as we ideally would be able to have complete follow-up to prevent any potential bias related to those athletes which we could not contact. However, our extended length of follow-up (minimum 10-year) may be expected to have some attrition, and our follow-up rate is even higher than previous studies on UCL reconstruction, including our 2-year follow-up study with 79% follow-up. Another potential limitation relates to recall bias as many of these players were asked to remember remote details of their baseball and post-baseball career. In most instances, we were able to utilize our prospective and 2-year follow-up databases as well as baseball database internet searches to confirm obtained information. Another limitation is that our data involves a follow-up study detailing one UCL reconstruction technique in baseball players by one surgeon; therefore, there might be some implications for generalizing the results to all UCL reconstruction techniques. Moreover, our group of baseball players is mostly composed of pitchers (90%), which is consistent with other studies evaluating outcomes after UCL reconstruction, and this point should be considered when extrapolating this information to baseball position players as well as other throwing athletes.

A final limitation to our study is that our data describes results of UCL reconstruction that were performed over 10 years ago. In fact, there may now be differences in diagnostic, surgical, rehabilitative, return to play, and on the field considerations that now allow for improved
optimization of treatment and recovery from UCL reconstruction. In fact, we are now better at
diagnosing these injuries in an expeditious fashion which may result in less severe pathology and
subsequently improved outcomes. In addition, our management of these athletes after they have
returned to play has improved as we now understand that it may take even 18 to 24 months
before achieving optimal on-the-field results after UCL reconstruction, especially in pitchers. By
further appreciating the unique nature of the return to play algorithm in these baseball throwers,
management and coaches now afford baseball players more time to return to play and are more
eagerly involved in improving mechanics, maintaining health, and preventing future injury in
these highly skilled and at risk athletes. Despite these limitations, our data appears to be
consistent with other short-term case series evaluating UCL reconstruction and may provide
important prognostic and preventative long-term information to physicians who treat overhead
athletes, especially baseball players.

CONCLUSION

Based upon baseball and post-baseball career variables, our study is the first to provide important
prognostic information relating to long-term outcomes (10-year minimum follow-up) after UCL
reconstruction with subcutaneous ulnar nerve transposition in baseball players. In agreement
with previous short-term studies concerning a competitive baseball career, our long-term follow-
up results confirm that UCL reconstruction may be effective in allowing most baseball players
(83%) to return to the same or higher level of competition in less than one year. We also present
unique prognostic data indicating that career longevity may portend multiple years of active
return to play (average, 3.6 years), with some variation depending upon the pre-operative level of play. Despite the level and length for return to play, the cause for retirement (86%) typically relates to other reasons independent of the elbow, except in cases of additional post-operative elbow surgery. Interestingly, a concomitant history of shoulder problems and/or surgery will most often result in retirement due to the shoulder and not the elbow.

In conjunction with their baseball career, long-term follow-up also indicates that most (93%) patients are satisfied, with few reports of persistent elbow pain (3%) and limitation of elbow function (5%) during activities of daily living. Almost all patients are also able to continue participating in recreational throwing activities, with most indicating no pain with throwing. According to our standardized disability and outcome scale, patients also have excellent results after UCL reconstruction during daily, work, and sporting activities. In fact, many patients are able to participate in activity/manual labor related jobs and baseball related activities, including coaching and/or instruction. Overall, baseball players who undergo UCL reconstruction for UCL insufficiency during their baseball career can expect excellent long-term follow-up outcomes in relation to their baseball and post-baseball career, with overall patient satisfaction in the setting of few cases of persistent elbow disability.
REFERENCES


2. Bennett GE: Shoulder and elbow lesions of the professional baseball pitcher. *JAMA* 117: 510-514, 1941


Figure 1. UCL reconstruction surgical approach for the ASMI Modification utilizing a flexor-pronator elevation ( mũi ) to the UCL along with an ulnar nerve (➡️) transposition. Note the first motor branch of the ulnar nerve (●●●➡️) in relation to the medial epicondyle (O) through the muscle split between the two heads of the flexor carpi ulnaris (➡️).
TABLE LEGENDS

Table 1. Background Data: Pre-operative Elbow Considerations as Based upon Pre-operative Level of Play.

* Significant difference among levels (p < 0.05)

Table 2: Background Data: Shoulder History and Post-operative Elbow History as Based upon Pre-operative Level of Play.

* Significant difference among levels (p < 0.05)

Table 3: Baseball Career Related Data: Post-operative Return to Play According to the Conway Scale as Based Upon Pre-operative Level of Play.

(NA – Not Applicable)

Table 4: Baseball Career Related Data: Post-operative Conway Scale in Relation to Independent Variables.

* Significant difference (p < 0.05)

Key:  
IP (Ipsilateral Palmaris)  
CP (Contralateral Palmaris)  
CG (Contralateral Gracilis)  
PL (Plantaris)
Table 5: Baseball Career Related Data: Post-operative Longevity and Retirement Etiology According to Pre-operative Level of Play.

* Significant difference among levels (p < 0.05)

Table 6: Baseball Career Related Data: Post-operative Conway 1 Longevity in Relation to Independent Variables.

* Significant difference (p < 0.05)

Key:
- IP (Ipsilateral Palmaris)
- CP (Contralateral Palmaris)
- CG (Contralateral Gracilis)
- PL (Plantaris)

Table 7: Baseball Career Related Data: Retirement Etiology in Relation to Independent Variables.

a Statistical significance related to elbow cause (p < 0.05)
b Statistical significance related to shoulder cause (p < 0.05)

Key:
- IP (Ipsilateral Palmaris)
- CP (Contralateral Palmaris)
- CG (Contralateral Gracilis)
- PL (Plantaris)

Table 8: Post-Baseball Career Related Data: DASH Scores in Relation to Independent Variables.

* Significant difference (p < 0.05)
Table 9: Post-Baseball Career Related Data: Baseball Retirement Activities According to Pre-operative Level of Play.

* Significant difference (p < 0.05)
FIGURES

Figure 1.
### Table 1.

<table>
<thead>
<tr>
<th>Level of Play</th>
<th>Previous elbow surgery*</th>
<th>Concomitant elbow procedure*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>13%</td>
<td>37%</td>
</tr>
<tr>
<td>Major League</td>
<td>25%</td>
<td>59%</td>
</tr>
<tr>
<td>Minor League</td>
<td>19%</td>
<td>45%</td>
</tr>
<tr>
<td>Collegiate</td>
<td>10%</td>
<td>33%</td>
</tr>
<tr>
<td>High School</td>
<td>0%</td>
<td>14%</td>
</tr>
</tbody>
</table>

### Table 2.

<table>
<thead>
<tr>
<th>Level of Play</th>
<th>Shoulder problems?</th>
<th>Shoulder surgery*</th>
<th>Post-operative elbow surgery*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>34%</td>
<td>25%</td>
<td>19%</td>
</tr>
<tr>
<td>Major League</td>
<td>46%</td>
<td>42%</td>
<td>38%</td>
</tr>
<tr>
<td>Minor League</td>
<td>38%</td>
<td>30%</td>
<td>28%</td>
</tr>
<tr>
<td>Collegiate</td>
<td>32%</td>
<td>23%</td>
<td>11%</td>
</tr>
<tr>
<td>High School</td>
<td>25%</td>
<td>13%</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Table 3.

<table>
<thead>
<tr>
<th>Level of Play</th>
<th>Higher Level</th>
<th>Same Level</th>
<th>Lower Level</th>
<th>Recreational</th>
<th>Unable to Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>40%</td>
<td>43%</td>
<td>7%</td>
<td>9%</td>
<td>1%</td>
</tr>
<tr>
<td>Major League</td>
<td>NA</td>
<td>79%</td>
<td>21%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Minor League</td>
<td>45%</td>
<td>31%</td>
<td>13%</td>
<td>9%</td>
<td>2%</td>
</tr>
<tr>
<td>Collegiate</td>
<td>38%</td>
<td>54%</td>
<td>1%</td>
<td>8%</td>
<td>0%</td>
</tr>
<tr>
<td>High School</td>
<td>58%</td>
<td>23%</td>
<td>3%</td>
<td>15%</td>
<td>3%</td>
</tr>
</tbody>
</table>

### Table 4.

<table>
<thead>
<tr>
<th>Return to Play</th>
<th>IP</th>
<th>CP</th>
<th>CG</th>
<th>PL</th>
<th>Graft Choice</th>
<th>Concomitant Surgery</th>
<th>Transient Ulnar Neuropraxia</th>
<th>Postop Elbow Surgery</th>
<th>Shoulder Problem</th>
<th>Shoulder Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>149</td>
<td>22</td>
<td>28</td>
<td>14</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Good</td>
<td>13</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fair</td>
<td>19</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Poor</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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</table>
Table 5.

<table>
<thead>
<tr>
<th>Level of Play</th>
<th>Post-operative Longevity</th>
<th>Retirement Etiology *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Years *</td>
<td>Conway 1 Years</td>
</tr>
<tr>
<td>Overall</td>
<td>3.6 ± 3.1</td>
<td>2.9 ± 2.9</td>
</tr>
<tr>
<td>Major League</td>
<td>7.5 ± 3.4</td>
<td>3.5 ± 3.3</td>
</tr>
<tr>
<td>Minor League</td>
<td>4.2 ± 3.5</td>
<td>2.9 ± 2.9</td>
</tr>
<tr>
<td>Collegiate</td>
<td>2.5 ± 1.9</td>
<td>2.8 ± 2.7</td>
</tr>
<tr>
<td>High School</td>
<td>2.9 ± 2.8</td>
<td>2.9 ± 2.8</td>
</tr>
</tbody>
</table>

Table 6.

<table>
<thead>
<tr>
<th>Postop Years</th>
<th>Graft Choice</th>
<th>Concomitant Surgery *</th>
<th>Transient Ulnar Neuropraxia</th>
<th>Postop Elbow Surgery *</th>
<th>Shoulder Problem</th>
<th>Shoulder Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IP</td>
<td>CP</td>
<td>CG</td>
<td>PL</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Average</td>
<td>3.6</td>
<td>4.1</td>
<td>3.7</td>
<td>2.7</td>
<td>4.3</td>
<td>3.1</td>
</tr>
<tr>
<td>P Value</td>
<td>0.644</td>
<td>0.007</td>
<td>0.339</td>
<td>0.015</td>
<td>0.102</td>
<td>0.031</td>
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</tbody>
</table>

Table 7.

<table>
<thead>
<tr>
<th>Conway Scale</th>
<th>Graft Choice</th>
<th>Concomitant Surgery</th>
<th>Transient Ulnar Neuropraxia a</th>
<th>Postop Elbow Surgery a</th>
<th>Shoulder Problem b</th>
<th>Shoulder Surgery b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IP</td>
<td>CP</td>
<td>CG</td>
<td>PL</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Elbow</td>
<td>104</td>
<td>12</td>
<td>18</td>
<td>6</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Shoulder</td>
<td>11</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Non Injury</td>
<td>34</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>Other</td>
<td>24</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 8.

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>DASH Scores (P Values)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DASH - Overall</td>
</tr>
<tr>
<td>Gift Choice</td>
<td>0.549</td>
</tr>
<tr>
<td>Concomitant Elbow Procedure</td>
<td>0.278</td>
</tr>
<tr>
<td>Additional Elbow Surgery</td>
<td>0.029 *</td>
</tr>
<tr>
<td>Pre-operative Elbow Surgery</td>
<td>0.305</td>
</tr>
<tr>
<td>Post-operative Elbow Surgery</td>
<td>0.042 *</td>
</tr>
<tr>
<td>Transient Ulnar Neuropraxia</td>
<td>0.028 *</td>
</tr>
<tr>
<td>Shoulder Problem</td>
<td>0.453</td>
</tr>
<tr>
<td>Shoulder Surgery</td>
<td>0.415</td>
</tr>
</tbody>
</table>

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Table 9.

<table>
<thead>
<tr>
<th>Level of Play</th>
<th>Baseball-Related Job *</th>
<th>Activity/Manual Labor Related Job *</th>
<th>Throwing Recreational Sports</th>
<th>Non-throwing Recreational Sports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>61%</td>
<td>58%</td>
<td>92%</td>
<td>70%</td>
</tr>
<tr>
<td>Major League</td>
<td>92%</td>
<td>75%</td>
<td>100%</td>
<td>71%</td>
</tr>
<tr>
<td>Minor League</td>
<td>74%</td>
<td>69%</td>
<td>93%</td>
<td>64%</td>
</tr>
<tr>
<td>Collegiate</td>
<td>50%</td>
<td>51%</td>
<td>92%</td>
<td>74%</td>
</tr>
<tr>
<td>High School</td>
<td>40%</td>
<td>38%</td>
<td>83%</td>
<td>75%</td>
</tr>
</tbody>
</table>